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ABSTRACT

Included are suggestions for constructing and using instructional flowcharts (IF) in science and mathematics classes. The use of instructional flowcharting was suggested as a way to enhance instruction techniques by avoiding unnecessary repetition of verbal directions for laboratory or problem solving sessions, as well as to avoid omitting or overlooking some major point in a discussion. IF's are included as well as examples of various uses of the technique.
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INSTRUCTIONAL FLOWCHARTING:

A TOOL FOR TEACHING SCIENCE AND MATHEMATICS

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Have you ever felt you were repeating the same verbal directions for laboratory or problem solving sessions (especially after five straight classes of chemistry or algebra)?

Do you wonder if the quality or clarity of what you say varies from presentation to presentation?

Have you ever become aware that you have omitted or overlooked some major point, and that backtracking to cover it seemed to reduce the impact?

Are you human? .

If you have experienced any of the frustrations listed above, perhaps instructional flowcharting is for you.

Have you ever wished for a technique which would serve to handle classroom management functions and even basic knowledge level learning functions with a minimum of effort in order to provide you the time to work with individual students?

Do you wish for something which would encourage the self-initiative of your students and discourage their extensive dependence upon you, the teacher?

If so, perhaps instructional flowcharting can help.

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INSTRUCTIONAL FLOWCHARTING

Flowcharting, the art of developing flowcharts, is a method of representing an algorithm for doing something which has a beginning, some well defined path or alternative paths, and an identifiable end point, or series of end points. Teachers with experience in computer programming will quickly recognize the symbols and logic of flowcharting. Those without such experience will have little or no difficulty in assimilating the operational skills of flowcharting.

A computer flowchart deals with the logic of programming computers; an instructional flowchart (IF) involves the logic of providing instruction for human learners. (The inference that human learners can be treated like computers is not intended by this analogy!)

Flowcharts have been used outside the field of computer science in popular texts, systems analysis, in research models, and in instructional development. They can and do provide a fascinating tool of instruction for many teachers. This article is an attempt to suggest how to construct and use instructional flowcharts in science and mathematics classrooms. A list of potential and realized advantages of IFs will also be used.

IF Symbols

One can develop IFs using the five basic symbols listed in Figure 1 below.

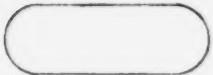
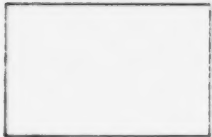
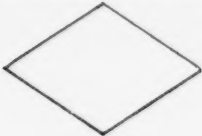
<u>Symbol</u>	<u>Symbol Name</u>	<u>Instructional Action Required</u>
	Terminal	Enter or exit the flowchart
	Process	Execute the statement listed inside Process symbol
	Decision	Answer the binary question
	Connector	Transfer to the indicated point in the flowchart
	Arrow	Signs which direct the flow between symbols

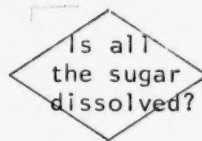
Figure 1. Flowchart Symbols (IBM Template).

Terminal represents both ENTRY into and EXIT from the algorithm. The ENTRY specifies the prerequisites (both cognitive and physical) needed by the learner to successfully engage in the instruction.

The rectangle, or process symbol, represents a direction requiring a response. Examples are:



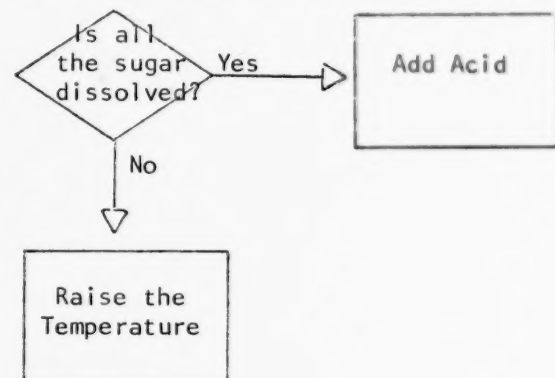
A diamond, or decision symbol, represents a question which requires a yes or no answer (binary decision). For example, in a laboratory exercise, the following decision may be important.



Complex decision sequences can be flowcharted by means of a series of interconnected diamonds.

The connector provides an imaginary line to any specified point in the flowchart; it is often used to avoid messy diagrams when the chart becomes complex or 'flows' onto multiple sheets of paper.

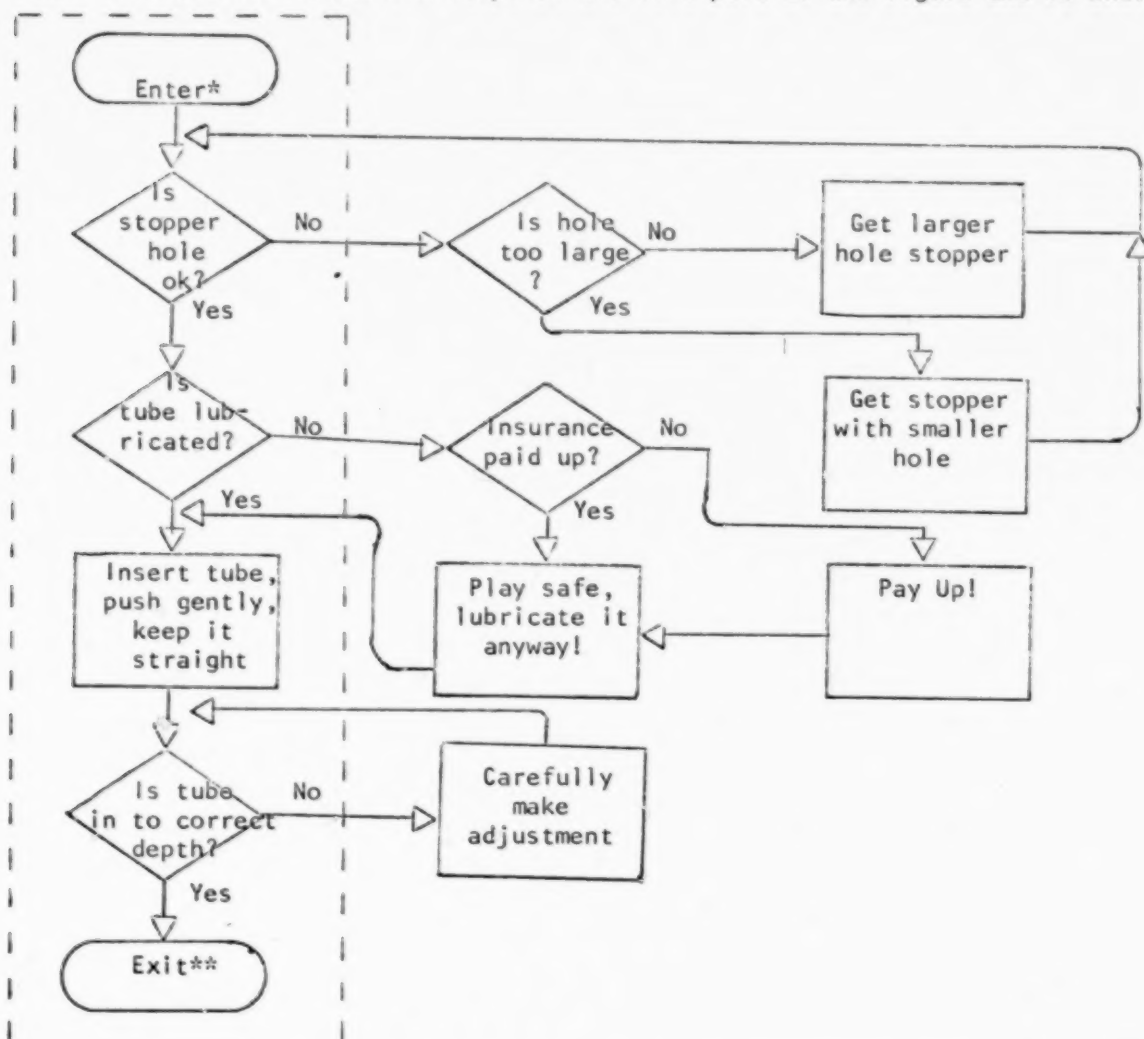
The flow of a flowchart is indicated by connecting the symbols by arrows in a meaningful fashion. Consider the short segment on the right which depicts a binary decision and different subsequent activities.



Arrows specify the "flow" of an IF. The basic arrow rules are that one and only one arrow must emanate from a process, terminal, a connector symbol, while two and only two arrows emanate from the decision symbol.

A Sample IF

Suppose you wish to provide written directions to chemistry students on safely inserting glass tubing in a rubber stopper and use a bit of humor to focus upon safety. The flowchart in Figure 2 is such a device. The main flow is contained in the six steps on the left part of the figure and is enclosed



*With glass tubing, rubber stoppers, lubricant

**To next part of the experiment

Figure 2. IF for Inserting Glass Tubing in Rubber Stopper.

in dashed lines. Note that there are three decision points in the main flow. A negative answer to any of these directs the flow into one of three loops or paths which eventually leads back to the main flow. These loops can be used to direct the learner's attention to points or concepts which you, the teacher, feel are important. The number and nature of loops is up to the discretion of the teacher. For example, some would include a decision symbol which asks if the tubing broke and was somebody cut. A yes answer to this would presumably branch the student to a first aid or 'call for the teacher' loop. This loop and others were excluded in Figure 2 for the sake of simplicity.

When used in conjunction with a series of photographs or drawings illustrating correct and incorrect procedures, and posted in an accessible place in the laboratory, this flowchart can provide a powerful safety impetus.

A second example, taken from mathematics instruction, is contained in Figure 3.

 Insert Figure 3 about here

USING IFS

The IF is an extremely versatile instrument in that it can be used for many purposes. The purposes to be illustrated here include classroom management, laboratory classification, and decision-making relative to environmental problems.

Classroom Management (CM)

CM refers to tasks which the teacher must complete that do not directly interact with the learning process and includes such things as laboratory techniques (Figure 2), keeping the supply room stocked, facilitation of equipment check-out, and meeting of schedules.

An example of an IF used for CM purposes will be drawn from the science methods course for Secondary School Teachers presently being taught at The Pennsylvania State University. Since this methods course is taught on an independent study basis, it is important that students possess a hard copy description of the way the course operates. In addition, this flowchart, seen in Figure 4, provides a model for the methods students for the flowchart which they will construct during the course.

Insert Figure 4 about here

Starting in the upper left corner of Figure 4, the student enters with the University prerequisites and attends the first 6 class meetings. The first diamond asks if the student has mapped out his own personal goals for teaching. A 'no' response sends him into a loop which requests him to make such a list.

A 'yes' response leads to two loops which in essence asks the student to check his personal goals against the requirements of the course and to develop alternative requirements in the event that any of his goals are not compatible with the course requirements.

On the right side of Figure 4, the student is requested to submit the first requirement and check to see if it meets the criteria. This decision loop is all important in the mastery learning model since there are definite alternatives to an unsatisfactory grade should the requirement not meet the performance criteria. Note that this feedback loop appears twice on the right side of Figure 4.

This flowchart is used to carry the main burden of describing to students and colleagues how the course operates. Numerous student questions have been answered by referring students to certain parts of the flowchart.

Laboratory Classification

Methods students develop at least one IF as a requirement for the science methods course. One student who subsequently completed her student teaching in Panama City used her flowchart which was subsequently adopted by the supervising teacher.

Another flowchart developed by a methods student and subsequently used during his student teaching is found in Figure 5. This chart describes identification of 10 specified minerals for classification purposes.

Insert Figure 5 about here

The logic of this IF will be left for the reader to pursue. It should be pointed out that this flowchart is a deliberate attempt to combine previously learned skills and facts into a simple classification scheme. Having this classification scheme available in IF form (rather than stored in the mind of the teacher) provides impetus for the student to assume responsibility for his own learning.

Decision-making

Flowcharts need not be restricted to memorize activities or routine performance of mundane activities. They can be used to lead students into fairly sophisticated learning behaviors. One key to the complexity of IFs (in terms of the cognitive functioning elicited) is the level and nature of questions in the diamonds. Questions may require observation (Is the sugar dissolved?), memory (Is this faster than the speed of sound in air?), or higher level thinking skills (Is this conclusion based upon empirical evidence?). In addition, questions may be convergent (Is the tube lubricated?) or divergent and open-ended (Have all factors been considered?).

An IF designed to develop decision-making skills in students should emphasize divergent and higher (than memory) level thinking questions. Figure 6 contains an IF which provides a model for decision-making relative to the resolution of environmental problems. This model is found in the minicourse called The Environmental Impact of Electrical Generation, Nuclear and Conventional, Pennsylvania Department of Education, 1971.

Insert Figure 6 about here

Some would argue that complex mental acts (such as decision-making) are not amenable to performance on the basis of a mechanical method (such as flowcharting). But there are good strategies or heuristics for arriving at such acts even when no sure-fire mechanical method exists (Concepts in Science Education, Michael Martin). The instructional flowchart can be useful in depicting salient components of the strategy, particularly to science students at the secondary level.

There seem to be two general rules which enhance the effectiveness of IFs. First, use each one in conjunction with a behavioral statement of what is expected of the student. Second, provide copies of each IF and the associated objective to students. One purpose of the IF is to facilitate communication regarding what the teacher expects the student to do. This act requires dispensing flowcharts to students.

ADVANTAGES

The chief benefits of IFs, from the point of view of the teacher or student, seem to be that they:

1. force the teacher to increase emphasis on being thorough and detailed (helps systematize classroom instruction),
2. provide replicable and permanent means of communication and instruction which can be updated,

3. like objectives, portray to students what is expected of them
(thus providing one opportunity for fostering student independence),
4. are flexible in that they can cover a wide range of intellectual and psychomotor skills,
5. force students to actively participate through considering questions posed in the diamonds,
6. can be used as a pedagogical tool which emphasizes that which the teacher wishes to emphasize,
7. provide a basic and inexpensive tool which can bring out a lot of creativity in teachers, and
8. are lots of fun for many teachers (and students) to construct.

If you're skeptical, pick up or construct a flowchart template, and create a flowchart which directs someone to:

1. get candy out of a candy machine,
2. make change as a store clerk during a purchase, or
3. complete a simple laboratory write-up.

But be careful, it's infectious!

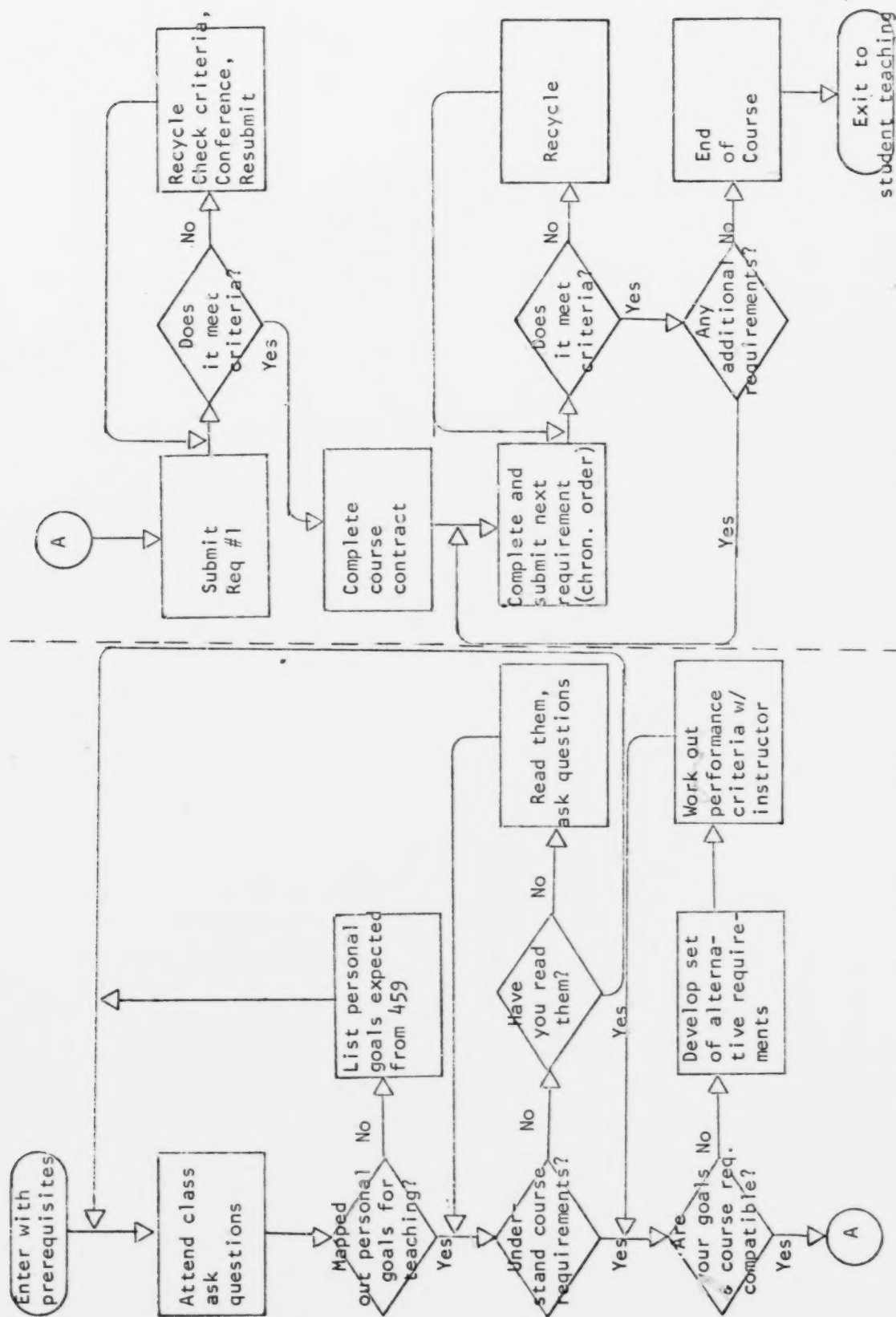
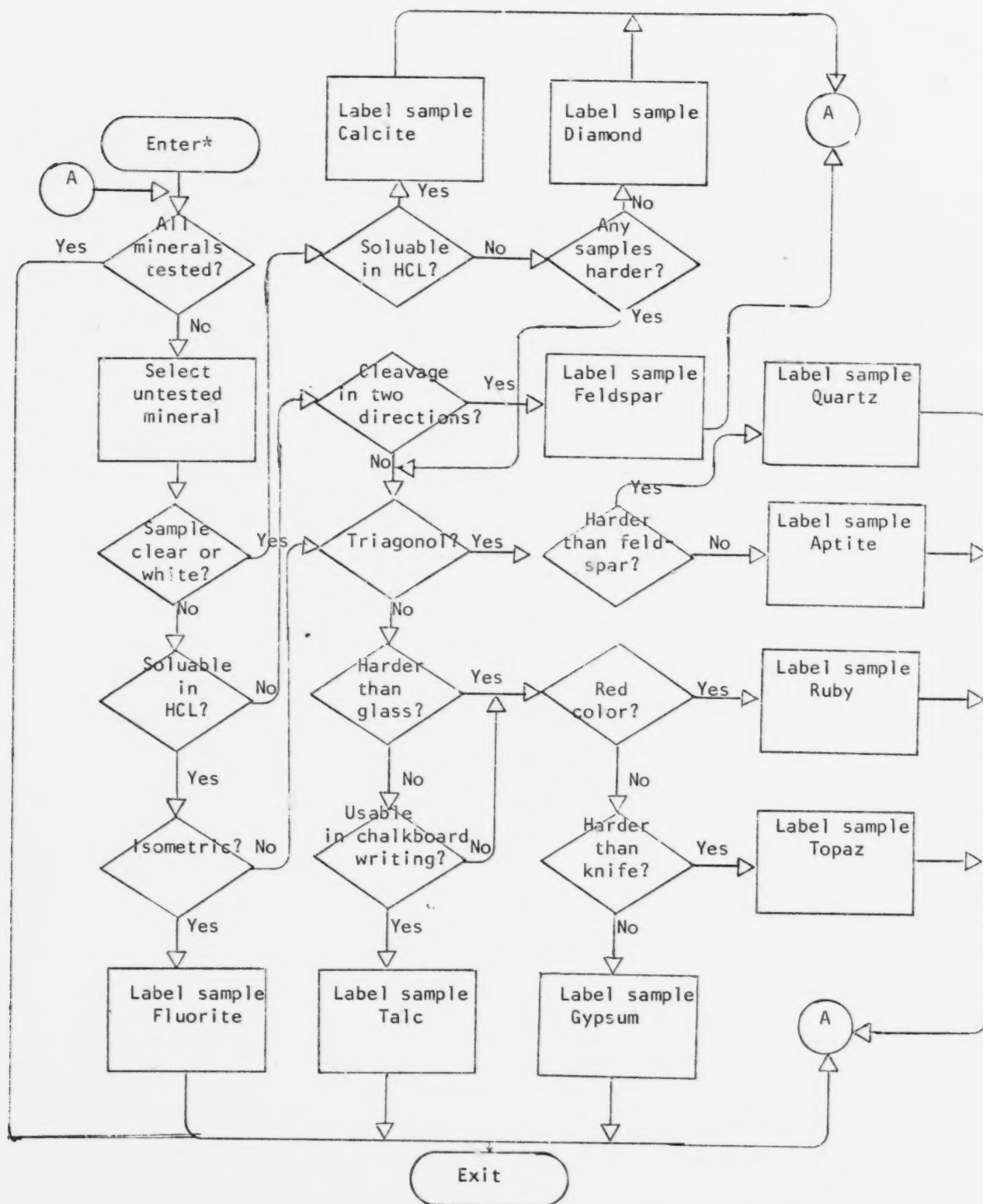


Figure 4. Generalized Flowchart for Completion of Science Education 459, The Pennsylvania State University.



*With 10 minerals, HCL, Hardness Testing Kit
Figure 5. Mineral Classification Flowchart.

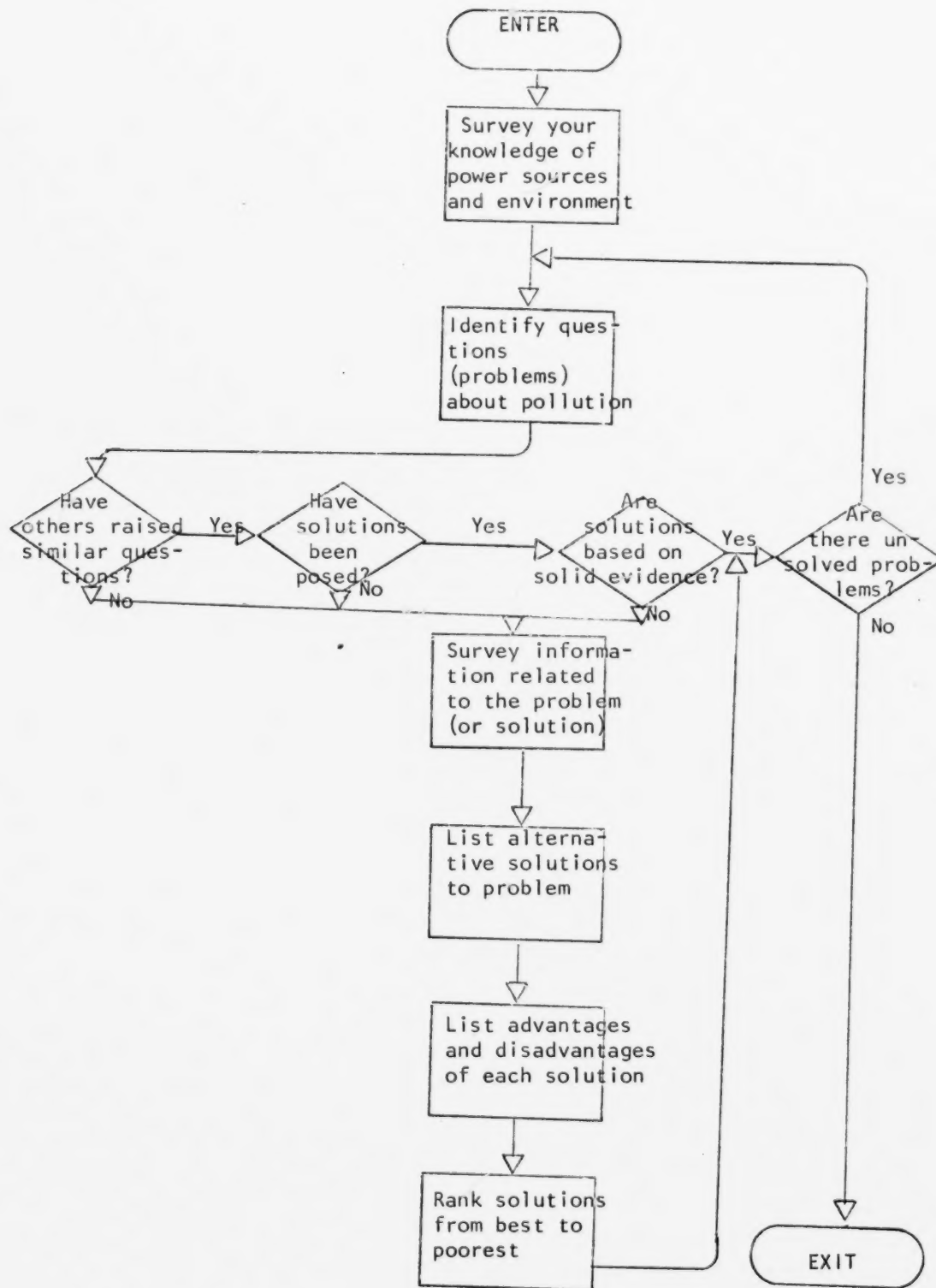


Figure 6 Flowchart of Basic Decision-Making Model for Resolution of Environmental Problems